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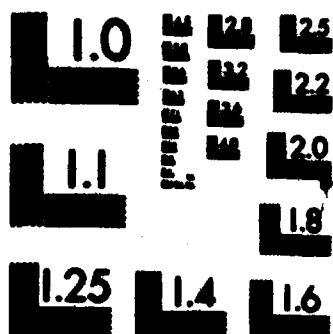
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German Quantum Optics Research in the Mirror
of the Annual Physical Society Meeting

Paul Roman

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<p>The 51st annual convention of the (West) German Physical Society, on 30 March through 4 April, in Berlin, hosted the very large meetings of the West German Quantum Optics Association. About 130 talks were presented. Nonlinear optics, nonlinear spectroscopy, lasers, laser applications, laser spectroscopy, ultrashort laser pulses, ultrashort phenomena, quantum-effects, bistability, and chaos were the session headings. This report covers selected topics from most of these areas. The conference reflected well the work currently done in the academia of the Federal Republic.</p> <p>presented 130 talks.</p>				
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GERMAN QUANTUM OPTICS RESEARCH IN THE MIRROR OF THE ANNUAL PHYSICAL SOCIETY MEETING

1 INTRODUCTION

The 51st Annual Meeting of the German Physical Society (West Germany) took place in West Berlin, 30 March through 4 April 1987. There were 497 talks presented, among which were 12 festive plenary session presentations, 34 keynote addresses in selected areas, 40 invited talks, six special reports, and six public lectures and teacher education seminars; the bulk of the presentations consisted of 403 contributed papers. There were also 130 posters displayed. A small book display, a history of laser research and classical physics demonstration, and an instrument exhibition provided pleasant distractions in the breaks. The language of the conference was German.

The bulk of the talks were organized by 10 divisions of the Physical Society. This report discusses solely the talks within the framework of the Quantum Optics Association (Arbeitsgemeinschaft Quantenoptik). The Director of these sessions was D. von der Linde (University of Essen). The proceedings of the quantum optics group included two plenary presentations, three keynote addresses, and 125 talks (some of them from invited speakers)--these regular talks were 15 minutes long and, almost always, excellently organized. The large fraction of presentations in the area of quantum optics (relative to the entire Physical Society meeting) clearly illustrates the strength of the field in West Germany.

The quantum optics talks were grouped essentially as follows:

- Nonlinear optics and nonlinear spectroscopy (three sessions)
- Lasers and laser applications, including laser spectroscopy (nine sessions)
- Ultrashort laser pulses and ultrashort phenomena (three sessions)
- Specific quantum effects, bistability, and chaos (three sessions).

No posters were accepted in the area of quantum optics--another sign of professional strength and standard-presentation.

In the following, I select topics which, because of my personal interests or other subjective reasons, caught my attention stronger than others. Even so, several fine contributions will be quoted only by title. However, I have a detailed book of abstracts (in German) and will be glad to supply xerox copies of selected areas to interested colleagues. A list of participants is also available, although it encompasses all participants of the entire Physical Society meeting.

2 SPECIAL PRESENTATIONS ON LASER SPECTROSCOPY

The festive plenary-talk in this area of lasers was delivered brilliantly by T.W. Hänsch (University of Munich), who talked about high-resolution laser spectroscopy of the simplest atomic systems. Latest experiments with hydrogen atoms permitted a determination of the Rydberg constant with an accuracy of 3×10^{-10} . The Lamb shift of the 1S ground-state was measured with an accuracy of 2×10^{-4} . Dramatic further increases of accuracy are expected from two-photon 1S-2S transitions. These experiments, as well as scheduled similar studies on exotic atoms (muonium or even anti-hydrogen), permit stunning tests of quantum electrodynamics--and perhaps of even deeper basic laws of physics.

A second, somewhat related plenary talk in the laser area was given by J. Mlynek (Federal Technical University, Zurich, Switzerland), who was this year's recipient of the German Physical Society's Annual Award. In his presentation he pointed out that level splittings with resonant energies in the high-frequency (RF) range may be studied successfully by using methods of nonlinear laser spectroscopy. In particular, coherent resonant Raman scattering, combined with optical heterodyning, opens up new possibilities in high-resolution spectroscopy, both in the frequency- and in the time-domain.

3 LASER DEVELOPMENT

General Topics

There was only one talk on dye lasers, so let me start with this apparently no longer "hot" topic. B. Neizert (Max Planck Institute for Quantum Optics, Garching) talked about extremely stable dye laser systems. High technical inventiveness characterized the work in which active frequency stabilization was imposed by using a high-Q, highly stable reference resonator and a fast positioning element in the laser resonator which was connected to a sophisticated regulatory circuit. At the same time, special architecture, acoustic and seismic isolation, and a novel dye-jet design improved passive stability.

Frequency stabilization was also the topic of a talk by G. Josko (University of Bonn) who used degenerate four-wave mixing to stabilize the 632.8-nm output of a He-Ne laser. The mixing of the split counter-propagating parts of the beam was done in an iodine cell. Before entering it, the pumping beam was frequency-modulated, and this was transmitted to the probing beam. Phase-sensitively extracted signals can then be used successfully to stabilize the laser operation.

M. Schneider (from the same university department) described yet another stabilization experiment. This talk was on saturation stabilization of a high-power CO laser.

Mode coupling via stimulated Brillouin scattering in multimode lasers was a joint contribution by scientists from the Max Planck Institute for Extraterrestrial Physics, Garching (H. Atmanspacher) and the Lebedev Physics Institute, Moscow, USSR. The calculated effect was demonstrated and studied in some detail in a dye-jet.

Probably the most unusual talk of the general laser development session was given by E. Schmidt (University of Bochum), who described the successful construction and 1500-hour operation of a novel, miniaturized, green-emitting HeSe⁺ metal vapor-gas laser. This device is pumped by charge exchange between the He ions and Se atoms in the positive col-

umn of a glow-discharge in a quartz capillary. (The Se is evaporated by an oven at the anode-side end of the capillary and transported by cataphoresis into the capillary, where it condensates.) The experimental HeSe⁺ laser operated in a sealed coaxial glass tube. When it was driven with approximately 200-W electric input power, it produced up to 10 lines in the region of 497 to 530 nm, and had a total output power of over 15 mW.

Ultraviolet Lasers

The contributed papers of the two UV laser sessions were preceded by a longer invited talk, read by R.R. Schlicher on behalf of the Max Planck Institute for Quantum Optics, Garching. The speaker reviewed the research group's current plans for developing a free electron laser (FEL) with a laser undulator, designed to produce soft x-rays. The laser undulator (replacing the conventional magneto-static undulators) would be provided by a pulsed high-power infrared laser beam. Apart from the fact that, if successful, this FEL would produce intensive coherent radiation with much higher frequencies than so far possible by any other kind of practical laser, it would also permit, for the first time, the study of quantum effects in a FEL. Although the feeding electron beam will not have to be very energetic, it is necessary that it have a high beam quality. Sufficient reflectivity of the "x-ray mirrors" terminating the resonator will also be a serious problem.

Not much more down to earth was the presentation of D. Goodwin (representing the Euratom Association in cooperation with the Max Planck Institute for Quantum Optics, Garching), which described a numerical model that indicated the possibility of a soft x-ray laser based on pumping of a plasma of H-like ions with suitably chosen visible light. This would produce quasi-stationary states with population inversion. The calculations include the effects of all collision- and radiation-induced transition processes between bound-states and the continuum, with careful attention to the level fine structures.

Two-photon excitation of molecular hydrogen can lead to stimulated emission in the VUV region, explained H.F. Döbele (University of Essen). He showed how, with narrowband 193-nm radiation (amplified in ArF to about 20-MW pulses 4 ns long), the rotational states of the E,F configuration can be excited. Subsequently, there will be four stimulated transitions in the Werner band, and 19 transitions in the Lyman band. Kilowatt output powers may be obtained.

A different approach to VUV or even XUV coherent radiation production was described by G. Hilber (University of Bielefeld). Detailed theoretical studies of resonant sum- and difference-frequency mixing of arbitrary high order in noble gases with arbitrary density distributions indicated that these processes can indeed lead to tunable, coherent very-far-ultraviolet radiation, provided there is careful optimization of parameters. Experiments were done on Kr, and continuously tunable radiation in the 72.5- to 83.5-nm or in the 127- to 180-nm region was indeed obtained. It even had "high spectral intensity."

In the area of more conventional UV lasers, perhaps the most interesting talk was by H.-J. Eichler and associates (Technical University, Berlin) who described a Cu^+ -ion laser which was equipped with a hollow cathode. Extremely stable, tunable laser radiation was obtained in the wavelength range of 248 to 270 nm, and the output power was well over 0.5 W. Longer than usually found lifetimes were obtained.

Excimer laser talks were mainly on technical improvements by Lambda Physik, Göttingen. M. Steyer (Max Planck Institute for Biophysics, Göttingen) discussed x-ray preionized XeCl and KrF lasers. Optimization was carefully studied.

The second UV laser session ended again with a curiosity: H. Nahme (Free University, Berlin) talked about luminescence radiation of solid noble gases. Crystalline Ar, Kr, and Xe were pumped by high-energy electron beams (with 2 to 50 J/cm^3 energy densities), which produced color centers with a density of 10^{18} cm^{-3} . Luminescence was seen between

126 nm (for Ar) and 172 nm (for Xe). The characteristics of radiation was studied, a theoretical model was constructed to explain the behavior, and the model was partially tested by excimer laser excitation of the noble gas crystals.

Solid-State Lasers

The majority of the presentations was in the area of color-center lasers.

A typical contribution, presented by K. Klameth (University of Hannover), described a CW-operating $(\text{F}_2^+)_\text{H}$ color-center ring laser. The centers were produced in $\text{NaCl}:\text{O}_2^-$. It was tunable between 1.4 μm and 1.85 μm , and it had a stable single-mode output with over 1 W power.

The University of Stuttgart was heavily represented in this area. W. Flassak talked about optical and structural properties of $\text{KMgF}_3:\text{Cu}^{++}$, in which lasing centers are produced via irradiation with ionizing beams, either at room temperature or at liquid nitrogen temperature. The centers can be excited by a 300-mW power output of a Kr ion laser (at 647 nm), and at liquid nitrogen temperatures it will show continuously tunable CW laser operation in the range of 950 to 1050 nm. A related talk (presented by G. Hörsch) reported on color-center laser action exhibited by $\text{KMgF}_3:\text{Pb}^+$. These systems can be pumped effectively by the 647-nm line of a Kr ion laser. At liquid nitrogen temperature tunable lasing between 855 and 965 nm could be seen. Room temperature operation seems also feasible. Finally, H.J. Paus gave a third talk from this Stuttgart group of researchers (which actually is under his supervision) and described studies on the laser operation of a flashlight-pumped $\text{MnF}_2:\text{Nd}^{3+}$ system at 1.06 μm and at 875 nm, at very low temperatures.

New types of garnet-based lasers, so popular about a year ago, seem to have lost their glamor. I mention here the talk by S. Struve (Spindler and Hoyer GmbH) on $\text{Cr}^{3+}:\text{GSAG}$ lasers with flashlight pumping, and the presentation given by O. Friedrich (University of the Bundeswehr, Hamburg) describing studies done on a GSGG laser which was synchronously pumped by a mode-coupled Kr ion laser.

The new trend in solid-state lasers is toward the use of sapphire-based devices. The University of Hamburg (under the leadership of G. Huber) seems to play an important role in this field.

T. Wegner talked about these basic optical properties of Mn^{3+} -doped Al_2O_3 which are relevant for laser operation. Broadband absorption occurs around 509 nm and fluorescence can be observed in two bands, between 650 and 750 nm. (Excitation was done with an Ar ion laser.) Photon counting indicated a 680- μs lifetime. Thus, Mn^{3+} appears to be very well suited to be an active lasing ion for the orange-red range, and the host sapphire has excellent thermal and mechanical properties.

Another talk from Hamburg, delivered by R. Horn, reported a study of the temperature dependence on the laser properties of titanium-doped sapphire. Carefully grown crystals permitted CW operation at room temperature. Tempering in a reducing atmosphere lowered the laser threshold considerably, and the slope efficiency was also high, around 6 percent.

Semiconductor Lasers

In the area of novel systems, I was impressed by the presentation of M. Tacke (Fraunhofer Institute, Freiburg) describing the successful construction with molecular beam epitaxy of double-heterostructures of $\text{Pb}_{1-x}\text{Eu}_x\text{Se}$. (The bandgap and the index of refraction was engineered by varying the Eu content.) Laser action in the mid-infrared (between 3 and 7 μm) was observed. In a subsidiary talk, A. Lambrecht explained how these active ternary double-heterostructures can be combined with a passive part that acts as a waveguide. In this way, new resonator configurations can be constructed.

Several talks discussed optical amplification.

E. Schöll (Technical University, Aachen) reported on a theoretical study: a dynamical model describing electrically modulated optical semiconductor-laser amplifiers. The main result of the calculations is that with a suitably chosen delay between the optical and the elec-

trical pulse, a strongly nonlinear deformation and shortening of the emitted laser pulse can be achieved.

Nonlinear properties of semiconductor laser amplifiers were also studied by G. Grosskopf (H. Hertz Institute, Berlin). His experiments used optical amplifiers which had strongly reduced reflectivity at the laser mirrors. Two optical waves (transmission channels) were coupled into the device, and, if intensity modulation was applied, cross talk could be observed. This nonlinear effect arises via the change of the complex index of refraction, and it depends on the optical input power.

4 ULTRASHORT PULSES AND ULTRAFAST PHENOMENA

The talks in this field varied from very basic research studies to rather standard practical applications, and I can give only a noncoherent review (pun not intended).

G. Angel (University of Bayreuth) talked on the production of femtosecond pulses with a pulsed dye laser system. He first gave a careful theoretical analysis that indicated how a dye laser, synchronously pumped with sufficiently strong beampulses of picosecond duration, may get, even within 100 cycles, into a stationary state consisting of femtosecond-pulses. The fastness of the build-up allows for moderating the demands on the precision of resonator length adjustment and on the nondispersivity of the optical components. In the experiments at Bayreuth, the model was fully justified. A Rhodamin 6G dye laser with a four-mirror resonator system was used. It was synchronously pumped with a 200-pulse-long train of a specially constructed Nd:Glass laser system. The length-adjusting criterion was found to be 100 times less stringent than when a continuous-wave synchronous pumping is used. In addition, the 10-fs pulses had an individual energy density of 0.1 μJ —several orders of magnitude higher than with a CW arrangement.

Femtosecond pulses were also the topic of the talk by D. Kuhlke (University of Essen). He observed that laser

pulses, of 628-nm wavelength of 80-fs duration and of about 0.3-mJ energy, display a pronounced spectral broadening when they traverse distances (over 1 m long) in air. Focusing of the pulses in the air leads to significant changes of the spectrum and to disturbance of the beam profile. Presumably, these phenomena are caused by a self-modulation in the air, amplified by a two-photon process in the nitrogen.

Pulse compression was discussed by two speakers. H. Roskos (Technical University, Munich) described studies regarding the compression of 90-ps pulses (obtained from a 1.06- μ m mode-coupled CW Nd:YAG laser). Parameters studied were: efficiency, pulse-shortening, and pulse quality. Using 25-m-long fibers, 4-ps pulses with 3-W average power were obtained; with a 1.3-km-long fiber, fully compressed pulses of 1-ps duration and 650-mW average power were achieved. (The input power in each case was 7.5 W.)

The second talk on pulse compression was presented by R. Schulz (University of the Bundeswehr, Hamburg). In this case, again, pulses from a Nd:YAG system were passed through a fiber-based grating pattern at powers both below and above the Raman conversion threshold. In the first case, 40-fold compression was obtained, leading to 1.8-ps pulses. In the second case, the pulses were compressed to 550 ps, but the spectral distribution was strongly asymmetric.

Picosecond pulses in the range between 1.18 μ m and 1.53 μ m were produced with a synchronously pumped ringlaser arrangement at the Max Planck Institute at Stuttgart, and were reported by H. Lobentanzer. The active medium was a dye (called "switch dye #5") and pumping was done, in the usual way, by a mode-coupled Nd:YAG laser. In this way, 27-ps infrared pulses were produced, with a maximum of 2-percent conversion efficiency. The importance of this result is that the output of the system may considerably improve research in the area of time-resolved IR-spectroscopy.

Subpicosecond-lasting laser plasma may be an interesting source of soft x-ray flashes. This was illustrated by

the talk of D. von der Linde (University of Essen). He explained that 150-fs laser pulses with 0.3-mJ energy and 616-nm wavelength were frequency-doubled in KDP, and then amplified to 8-mJ power by passing them through several stages of a XeCl excimer laser amplifier. These ultraviolet subpicosecond pulses were then focused on various metallic surfaces--giving rise to very short x-ray bursts from the resulting plasmas.

I conclude this section with a report on the talk of R. Leonhardt (Technical University, Munich) who reported a spectroscopic "first": time-resolved coherent anti-Stokes Raman spectroscopy (CARS) in the femtosecond domain. A unidirectional femtosecond ringlaser (wavelength 620 nm, pulselength 60 fs) was synchronized with a second, tunable dye laser (6-ps pulse length radiation). With the stabilized ringlaser output CARS experiments were successfully performed in several cases. For example, phase relaxation times in liquids that were shorter than 1 ps could be studied. Also, vibrational modes with frequencies up to 10 THz could be measured with precision.

5 NONLINEAR OPTICS

The keynote address was given by G. Marowski (Max Planck Institute, Göttingen). He explained how reflexion, refraction, polarization, and critical angles on the surfaces of solids can be innovatively studied by methods of nonlinear optics. As a specific example Marowski reported on his experiments related to the determination of orientations of adsorbates. He also gave a systematic description of nonlinear optical properties of large organic molecules.

L. Arnold (Max Planck Institute for Quantumoptics, Garching) gave a report on continuing experiments at Garching (see ESN 40-8:287-290) regarding laser frequency mixing with a scanning tunneling microscope (STM). Light from two tunable CO₂ lasers was focused onto the tungsten tip. Difference frequencies up to 50 MHz were observed and the dependence of mixing on voltage bias, tunnelling current, and tip-to-surface distance was established.

P. Fenz (University of Marburg) talked about nonlinear frequency mixing in semiconductor lasers. The mode coupling in such devices (and also in passive waveguides) is largely determined by the 3rd-order susceptibility $\chi^{(3)}$. Thus, intracavity four-wave-mixing experiments allow a clever determination of $\chi^{(3)}$, provided the intensity distribution of the mixing frequencies is experimentally established. In these studies, simultaneous appearance of frequency mixing in several longitudinal modes was also seen.

Nonlinear optics in Langmuir-Blodgett films was the exciting topic presented by S. Draxler (University of Graz, Austria). The film technique permitted the researchers to build up layered systems with high optical quality and without inversion-symmetry, so that the molecular nonlinearity was macroscopically preserved. Frequency doubling and frequency mixing were demonstrated.

The group of H.-J. Eichler (Technical University, Berlin) presented nice phase-conjugation studies (both experimental and theoretical), occurring in four-wave-mixing in a Si crystal. Using a 1.06- μm Nd:YAG beam with 15-ns pulse length, reflexion coefficients over 100 percent were found, provided the pumping energy density was not less than 0.1 J/cm².

Next, I call attention to the talk by P. Tepper (Free University, Berlin), who drew attention to the usefulness of studying frequency doubling on the surface of ionic crystals, such as BaF₂ and NaCl. By measuring the anisotropy of the frequency doubling efficiency rate when the crystal face was rotated around the normal axis, it was possible to deduce various surface features, including dislocations. During the measurements a fixed combination of the fundamental and of the second harmonic wave polarization was arranged for.

Two interesting talks in the area of nonlinear optics were given in a "wrong" session, entitled "Laser Applications," that were concerned with a variety of mostly technical and diagnostics topics. I find it better to report these two talks at this point.

H.-J. Eichler discussed the amplification of picosecond pulses by means of two-wave mixing in silicon. (This research really complements the one by Eichler, on four-wave mixing, reported above.) A weak signal beam of a Nd:YAG laser (1.06 μm) was superimposed in a 400- μm -thick Si crystal onto a coherent pump beam (taken from the same laser). This caused the formation of dynamical charge-carrier gratings. Diffraction of the pump beam in the direction of the signal beam leads to amplification of the latter. Experimental and theoretical studies were done to determine the dependence of the amplification on various parameters. With 0.1-J/cm² pumping energy density, a maximum amplification by a factor of 20 was observed.

Laser-induced gratings, in a quite different setting, were also at the heart of the talk by V. Becker (University of Frankfurt), who reported on nondegenerate and degenerate self-diffraction on laser-induced gratings in CdS. The spectral dependence of the reflected 1st-order diffraction was studied, as well as the diffraction efficiency. The experiments were done between 8 and 78 K. The lattice constant was also varied.

6 OPTICAL BISTABILITY

Perhaps the most unusual talk presented in this field was given by W. Schulz (representing both the University of Munich and the Max Planck Institute for Quantumoptics at Garching), who described current and planned experiments for studying optical bistability with Rydberg atoms. The major point of the study was to determine the minimum number of atoms and photons that must be present to achieve bistable behavior. (In bistable systems the fluctuation processes are inversely proportional to the particle number.) The experiments are made feasible because of the extremely strong coupling between the Rydberg atoms and the electric field, so that the atomic transition frequencies lie in the microwave region. Highly excited Rb atoms passed through a ring resonator made from superconducting Nb. The very high transition

dipole moments between adjacent Rydberg levels allow for very low photon numbers, even as few as 10. Hence, fluctuations will influence the dynamic behavior of the system to an extreme degree.

Another novel idea in optical bistability (of probably only limited possibilities) was put forward by V. Glaw (Technical University, Berlin). He constructed a multistable device which consists of a nonabsorbing Fabry-Perot interferometer (FPI) etalon and an attached absorbing layer. The etalon is tuned by the heat conduction from the absorber, which, in turn, is heated up by the incident light. The switching behavior depends on the direction of incidence. In the actual experiments, glass etalons with dielectric reflectors and a vapor-deposited CdS absorber layer were used. The principal advantage of this new type of bistable device is that the FPI itself does not absorb light and therefore has a very high finesse.

7 CONCLUDING REMARKS

The Berlin meeting gave a good impression of the breadth and depth of West German research in optoelectronics, laser

science, and modern optics. Of course, since the meeting was organized within the larger framework of the Physical Society's annual convention, the spectrum of speakers was somewhat restricted to scientists from academia--industrial research laboratories' contributions were practically non-represented. Even within academia, the overwhelming majority of speakers came from physics departments, and very few researchers from engineering schools were seen.

Among the establishments that apparently dominate the scene, (irrespective of special subfields), we find the Garching and Stuttgart Max Planck Institutes, the Technical University of Berlin, and the two universities in Munich. Hamburg is also very strong, and Hannover is coming up fast. But these are mostly personal impressions and are probably a bit biased by the selection process of the speakers, as must always be the case at meetings of a national society.

The atmosphere was lively, confident, civilized, disciplined, and very friendly. The organization was good and a bit frugal. The gracious host of the meeting was the modern and still growing Technical University of Berlin.

END

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